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Impact of smoking and preoperative electrophysiology on outcome after open carpal tunnel release

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Abstract

Background: Our aim was to evaluate the influence of smoking and preoperative electrophysiology on the outcome of open carpal tunnel release.

Methods: This retrospective observational study evaluated the outcome in 493 patients (531 hands) primary operated for carpal tunnel syndrome. Data were collected from medical records, health evaluations and QuickDASH questionnaires before surgery and one year after.

Results: Smokers had a higher QuickDASH score preoperatively as well as postoperatively, but the change in total score did not differ. The odds of having a postoperative QuickDASH score >10 were 2.5 higher in smoking patients than in non-smoking patients. In 124/493 patients (25%), no clinically significant improvement was seen. Normal and extreme preoperative electrophysiology values were associated with higher postoperative scores. No correlation was found between preoperative QuickDASH scores and preoperative electrophysiology values.

Conclusions: Smokers with carpal tunnel syndrome experience more symptoms preoperatively. Smokers have remaining symptoms after surgery. There is no correlation between preoperative QuickDASH scores and preoperative electrophysiology values. Patients with normal or near to normal preoperative electrophysiology results have limited improvement after surgery.

Key words: carpal tunnel syndrome, carpal tunnel release, smoking, electrophysiology

Introduction

The most common nerve compression in the upper extremity is carpal tunnel syndrome (CTS), particularly frequent among women and patients >55 years of age (Atroshi et al., 1999). Risk factors for development of CTS include overweight (Lam and Thurston, 1998), diabetes (Hou et al., 2016) and exposure to hand held vibrating tools (Tseng et al., 2012). There are conflicting results concerning smoking as a risk factor for developing CTS (Geoghegan et al., 2004, Maghsoudipour et al., 2008, Nathan et al., 2002), and it has been reported that symptom resolution is less frequent in current smokers following surgical release (Coggon et al., 2013).

Treatment strategies in patients with CTS depend on severity of symptoms, where mild symptoms can be treated with splinting and self-care instructions, whereas for moderate to severe symptoms surgical treatment is recommended. When diagnosing CTS and choosing patients suitable for surgical treatment, nerve conduction studies are often used to assist in the decision-making. It has been implied that patients with normal and near-normal electrophysiology values, as well as those with extremely pathological electrophysiology values, may benefit less from surgical treatment (Bland, 2001). However, no correlations seem to exist between nerve conduction, symptom severity and outcome of surgery in patients with CTS (Longstaff et al., 2001).

The standard surgical procedure at our hospital is open carpal tunnel release (OCTR). It is generally known to have a favorable outcome (Scholten et al., 2007). However, in some patients the outcome is not satisfactory in spite of an adequate surgical procedure.

We aimed to evaluate outcome of OCTR, using the QuickDASH (Disability of Arm, Shoulder and Hand) questionnaire (Zimmerman et al., 2016) (Dahlin et al., 2016), with focus on the influence of smoking and preoperative electrophysiological findings. In addition, we assessed the characteristics of the patients who did not improve following the surgery.

Materials and Methods

We conducted a retrospective observational study on patients who underwent OCTR at our hospital from September 2009 to February 2011. Patients were identified through the hospital administrative register by the operation code ACC51. QuickDASH questionnaires are routinely sent out to all patients planned for surgery at our department. Patients who had completed a valid questionnaire preoperatively and one year after surgery were included. Patients who were re-operated during the study period because of persistent or recurrent symptoms were excluded, since our aim was to investigate the outcome of primary releases, and re-operations come into a completely different category that could include recurrence, inaccurate diagnosis and inaccurate treatment.

QuickDASH total score ranges from 0-100 (the higher the score, the more disability) (Zimmerman et al., 2016). The Swedish version of QuickDASH was used (Gummesson et al., 2003). An eight point change from QuickDASH score preoperative to postoperative follow-up has been suggested as the minimal clinically important difference (Mintken et al., 2009) and a postoperative total score of more than ten is considered to represent persistent disability (Hunsaker et al., 2002).

Data were collected from medical records and from a declaration of health that patients completed preoperatively. Preoperative electrophysiology findings were classified as described by Padua (Padua et al., 1997), using sensory conduction velocity in the median nerve over the wrist (SCV). The electrophysiology findings were classified accordingly as negative (normal findings), minimal (solely abnormal segmental and/or comparative studies), mild (abnormal digit = wrist conduction and normal median distal motor latency), moderate (abnormal digit = wrist conduction and abnormal median distal motor latency), severe (absence of sensory response and abnormal median distal motor latency) or extreme (absence of thenar motor responses). For the sake of simplicity, we present the patients classified as negative and minimal ad modum Padua together as normal. A consultant in clinical neurophysiology evaluated all measurements. We also used sensory nerve action potential amplitude (SNAP) in the median nerve recorded from the long finger as a measurement of the number of functioning nerve fibers. SNAP is a recording of the number of excitable sensory axons – a higher SNAP indicates better sensory functioning (Robinson, 2015).

Continuous data are presented as median [interquartile range, IQR]. Mann-Whitney U-test was used for comparing continuous data. Nominal data presented as number (%) and evaluated by chi-square test. Kruskal Wallis test was used to calculate significance of differences if more than two groups were compared, with a subsequent Mann-Whitney U-test. Spearman's correlation was used to correlate neurophysiological values and preoperative QuickDASH total score. A binary logistic regression was used to calculate odds ratio (OR). A p-value < 0.05 was considered statistically significant.

Ethics

The study protocol was presented to the regional Ethics Committee (#2011/607). They found the study sound, without ethical problems and judged that the study was not applicable in the Swedish Ethical Review Act. Neither advertising nor formal informed consent by each patient was needed. Chief of service at our department approved the quality control. Therefore, no formal permission number has been attached to the study.

Results

493/962 patients were included in the study (Zimmerman et al., 2016). Thirty-eight patients were operated bilaterally during this period; they completed two separate QuickDASH questionnaires (one per hand) and are included as one operation with mean QuickDASH scores.

Excluded patients, i.e. not completing both pre- and postoperative questionnaires or having a reoperation, were younger (median 47 [IQR 38-56] years) than the included patients (55 [46-66]; $p<0.0001$), but did not differ with respect to gender [data already published, (Zimmerman et al., 2016)]. The effect of diabetic status, obesity, hypertension, polyneuropathy and statin treatment on surgical outcome is also addressed in another manuscript from the same study population (Zimmerman et al., 2016).

The number of smoking patients in the population was 94/493 (19%) (missing data about smoking status in seven patients). Patients who smoked were younger and their preoperative median nerve sensory conduction velocity at wrist level was higher than the non-smoking patients (Table I). Smoking patients had higher SNAP in the middle finger than non-smoking patients ($p=0.003$; Table I). They had a higher QuickDASH total score both preoperatively ($p<0.0001$; Table II) and postoperatively ($p<0.0001$; Table II) compared to non-smoking patients, but there was no difference in the change in total score. However, a higher number of smoking patients had a postoperative total score >10 ($p<0.002$; Table II) and fewer of the smoking patients had a change >8 and postoperative score <10 ($p<0.008$; Table II). The odds indicating persistent symptoms, i.e. postoperative QuickDASH score >10, were higher in smoking patients than in non-smoking patients (Table III).

When analyzing separate questions in the QuickDASH, smoking patients scored higher on item ten “severity of tingling (pins and needles) in your arm, shoulder or hand in the last week” than non-smoking patients postoperatively (median 2.0 IQR 2 vs. median 1.5 IQR 2, p<0.05). Smoking patients also scored higher on item nine “severity of arm, shoulder or hand pain in the last week” both preoperatively (median 4.0 IQR 1 vs. median 3.0 IQR 2, p<0.0001) as well as postoperatively (median 3.0 IQR 2 vs. median 2.0 IQR 2, p<0.0001). Smoking patients rated item 11 “during the past week, how much difficulty have you had sleeping because of pain in your arm, shoulder or hand?” higher than non-smoking patients preoperatively (median 4.0 IQR 1 vs. median 3.0 IQR 2, p<0.0001) and postoperatively (median 2.0 IQR 2 vs. median 1.0 IQR 1, p<0.0001).

In 124/493 (25%) patients, there was a change in QuickDASH total score <8. In this group, there were more patients diagnosed with polyneuropathy (diagnosis found in medical records or in preoperative neurophysiological statement) (p=0.01; Table I). Patients with a change <8 had higher sensory conduction velocity in the median nerve at wrist level than patients with a change >8 (p=0.02; Table I). Patients with a change <8 also had higher SNAP in the middle finger than patients with a change >8 in the QuickDASH (p<0.05; Table I). The patients with less improvement (i.e. change <8) also had higher postoperative QuickDASH total score (p<0.0001; Table II) and there were more patients in this group with a postoperative total score of >10 (p<0.0001; Table II).

Of the 299 patients that had undergone preoperative electrophysiology testing, 26 (8%) were classified as normal (i.e. negative and minimal), 30 (11%) as mild, 123 (43%) as moderate, 63

(23%) as severe and 43 (15%) as extreme. Seventeen patients could not be assessed due to missing data or severe polyneuropathy and they were therefore excluded in the evaluation.

There was no difference in the preoperative QuickDASH score between any of the electrophysiology groups (p =0.73), or in the change in total score (p=0.11). However, the postoperative QuickDASH scores differed between the electrophysiology groups (p=0.046), where patients classified as having normal values as well as the patients with extreme CTS had higher QuickDASH scores postoperatively than those graded as severe (both p=0.02; Figure 1). There were differences in the number of patients with a postoperative change in QuickDASH score <8 with respect to electrophysiological classification (chi-square p=0.025) (Figure 2). When comparing the adjacent groups, we found that the group classified as mild had higher postoperative scores than the group classified as moderate (p=0.04).

The distribution of age varied between the different groups (Kruskal-Wallis p<0.0001). Patients classified as extreme were oldest (median 71 IQR 25 years), whereas the patients classified as normal were youngest (median 48 IQR 18 years). The other groups' age distribution was as follows: mild: median 60 IQR 18 years, moderate: median 53 IQR 16 years and severe group: median 63 IQR 23 years. Significance was found between normal and severe (p=0.001), normal and extreme (p<0.0001), moderate and severe (p=0.001), moderate and extreme (p<0.0001).

Twenty-six patients had normal electrophysiology values, and only 15 of these had a clinically significant improvement (i.e. QuickDASH change >8). Twenty-one of the 26 patients (81%) with normal electrophysiology values had a postoperative total score of >10.

In the logistic regression, neither the preoperative sensory conduction velocity (SCV) in the median nerve over the wrist nor the SNAP in the middle finger affected the odds of having a postoperative score >10 (Table III). SNAP slightly increased the OR on total score change <8 in the univariate analysis and in the first model (Table III).

There was no correlation between the preoperative total scores and the preoperative sensory conduction velocity in the median nerve at wrist level (Figure 3). No correlation was found between preoperative total scores and SNAP in the middle finger (Spearman's r -0.003, n=312, p-value >0.05).

Discussion

Current tobacco smoking in patients with CTS increased the severity of the preoperative symptoms and was associated with persistent symptoms following OCTR. Smokers improved their QuickDASH scores to the same extent as non-smokers after OCTR, but they experienced more symptoms since a) they had higher postoperative QuickDASH scores, b) more smokers had a total score of >10 postoperatively c) less smokers had a change >8 and a postoperative score <10 and d) smoking increased the odds of having a postoperative score >10. A few studies have pointed towards smoking as a risk factor for developing CTS (Geoghegan et al., 2004, Maghsoudipour et al., 2008, Nathan et al., 2002), and smoking is associated with more persistent symptoms after surgery for CTS (Coggon et al., 2013). We show that smoking patients may benefit from surgery to the same extent as non-smokers, but smoking seems to be associated with worse symptoms before surgery as well as more persistent symptoms after surgery. The pathophysiological mechanism behind smoking as a risk factor for CTS is not known, but it could be related to a decreased intraneural blood flow leading to hypoxia since microvascular factors are crucial for development of CTS (Rempel et al., 1999). The smokers may have less structural alterations in the compressed median nerve, since they had a better nerve function preoperatively, as indicated by a higher sensory conduction velocity at wrist level and higher SNAP compared to non-smokers.

In addition, smoking may alter pain sensation (Carstens et al., 2001, Nakajima and al'Absi, 2011), which may be one contributing reason to why the smoking patients with CTS reported more symptoms both pre- and postoperatively than the non-smoking patients. There was also a difference in the pain-related items in QuickDASH (pain, tingling and difficulty sleeping due to pain), where the smokers rated themselves higher on all these items than non-smokers, both before and after surgery. This might indicate that there is a difference in how pain from CTS is perceived dependent on smoking status. It is possible that smoking patients experience more symptoms earlier than non-smoking patients, leading to an earlier diagnosis and earlier treatment. It is however difficult to evaluate if this has an effect on the treatment results since we have no data on symptom duration. Also, the severity of the nerve compression depends not only on the duration but also on the amount of elevated pressure on the nerve. One may nevertheless speculate that smoking patients with CTS can improve their symptoms by smoking cessation, regardless of surgery, and we would like to suggest that smoking patients should be advised to stop smoking before OCTR, as this could possibly improve postoperative results.

Our data also showed that 124 out of 493 patients (25%) did not experience a minimally clinically important improvement; i.e. had a change less than 8 in QuickDASH total score (Mintken et al., 2009). We have no apparent explanation for this observation. There was no significant difference in how these patients rated their preoperative symptoms compared to the rest of the patients. The variables that differed in the group of patients with a QuickDASH change <8 were that they had slightly higher conduction velocities at wrist level and SNAP in the middle finger preoperatively and that there was a higher proportion of patients with polyneuropathy; thus, there was slightly less potential for improvement. Still, it is worrying that such a large number of patients did not benefit from the surgery. It was recently reported that symptoms in patients, who cancelled OCTR, improved over time, even though they did not receive any surgical treatment (Pensy et al., 2011). In our opinion, this stresses the importance of a correct diagnosis, and perhaps conservative treatment options should be used to a higher extent before proceeding to surgical treatment, at least for patients with mild symptoms. One may note that the QuickDASH does not assess if the patient is satisfied with the surgery and that other conditions in the upper limb (other than symptoms originating from the hand) may influence the results. We evaluated results one year after surgery, while another recent study showed that a majority of patients operated on with OCTR was completely or very satisfied, using Levine-Katz symptom and function scales, with the surgery after ten years (Louie et al., 2013).

In the present study, electrophysiological findings supported the diagnosis in 67% of the patients. The American Association of Orthopedic Surgeons (AAOS) recommends the use of electrophysiological tests if clinical and/or provocative test are found positive, and surgical treatment is considered (AAOS Guidelines, 2007). In our region, it is generally recommended to perform electrophysiology testing before surgery only if the patient presents non-specific clinical symptoms to ensure an accurate diagnosis. Previous studies have shown no correlation between the findings on electrophysiology and the patient's symptoms (Itsubo et al., 2009, Longstaff et al., 2001), and the present data support this notion (Figure 3). Electrophysiology is a good method to grade the severity of compression, but it does not measure the severity of carpal tunnel syndrome as experienced by the patient (Turner et al., 2010). A slightly compressed nerve may induce severe symptoms, while at later stages (i.e. more or longstanding compression) such symptoms may disappear.

Our interpretation of why such a large proportion of our patients hade undergone an electrophysiology testing before surgery is that many patients were referred directly to surgery from the general practitioner in the primary health care system. A higher level of knowledge regarding the clinical features of carpal tunnel syndrome in the primary health care setting might help to reduce the number of unnecessary electrophysiology examinations.

Only 15/26 patients with normal electrophysiology values had a clinically significant improvement (change >8 in QuickDASH score), indicating that some patients may even have an incorrect diagnosis. Normal nerve conduction values have previously been associated with worse surgical outcome (Bland, 2001), though it is known that patients with CTS can present without pathological electrophysiology values (Finsen and Russwurm, 2001). It has also been shown that electrophysiology alone could not predict patient recovery after surgery (Braun and Jackson, 1994). Our results indicate that patients with extreme CTS are alleviated by surgical intervention, but may have persistent symptoms indicating that they have already suffered permanent nerve damage. Electrophysiology may be a complement to the clinical examination in complicated cases, but it cannot alone guide the choice of treatment.

A limitation of this study is that 469 patients did not answer both QuickDASH questionnaires or underwent a reoperation and were therefore not included in the study. We cannot with certainty rule out the possibility that data from the non-responders may influence the results. Unfortunately, we do not have any more data on the excluded patients. In addition, since the QuickDASH formula is not disease specific, other arm/shoulder/hand-problems may affect the score, but we had no detailed information about other symptoms in any patients.
Regarding smoking status, we unfortunately do not have information on how much the patient smoked. We also cannot report any clinical outcome after surgery, since no postoperative clinical controls were performed. We can only draw our conclusions from the self-reported symptoms in the QuickDASH, and we do not have any objective data on the surgery outcome.

One might, however, argue that the most important factor in surgery outcome is the patient's experience of symptom resolution.

The QuickDASH is a validated questionnaire and is routinely used at our clinic to evaluate surgery outcome. However, it is not disease specific. In this study, we looked closer into some items in the QuickDASH in an attempt to assess symptoms specific for carpal tunnel syndrome. We also included some patients who were bilaterally operated during the study period and since some of the items in QuickDASH are bimanual tasks, this might influence the results.

In the logistic regression, we included electrophysiology data, which unfortunately meant that many patients could not be included in the calculation, since many of our patients did not undergo nerve conduction studies prior to surgery. This might influence the accuracy of the statistics.

Conclusions

Our results demonstrate that smokers with CTS experience more pre- and postoperative symptoms. Smokers with CTS improve by OCTR, but experience remaining disability. Patients with normal or mild electrophysiology results have limited improvement after surgery. Preoperative electrophysiology does not correlate with the patient's symptoms as measured in QuickDASH. We emphasize that if the patient´s symptoms and findings in clinical examination is typical for CTS, it is not necessary to refer such a patient to a preoperative electrophysiology test.

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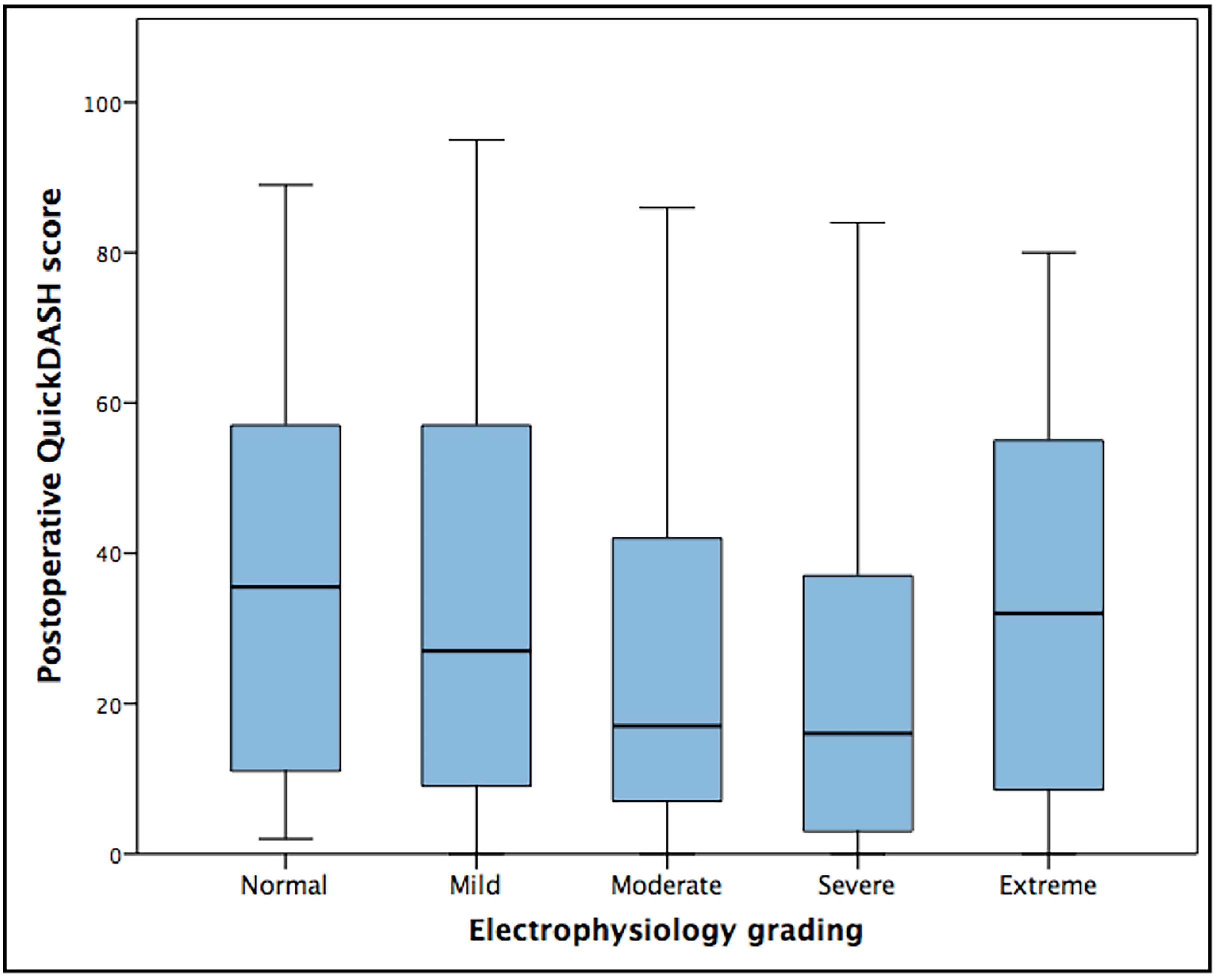
Figure legends

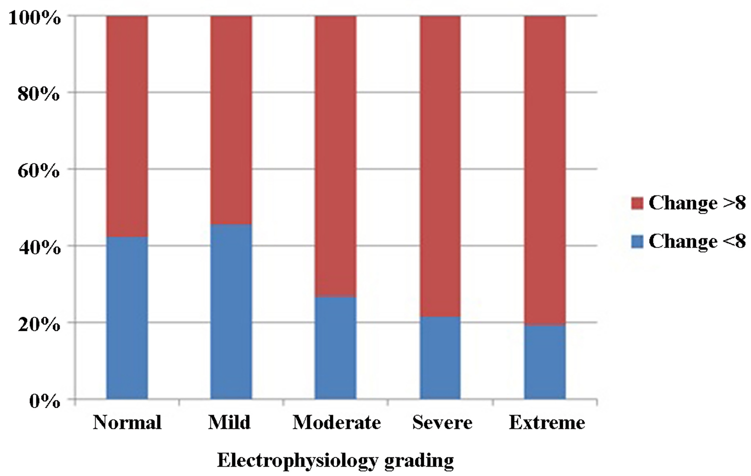
Figure 1. Postoperative outcome in relation to electrophysiology grading. Groups according to preoperative electrophysiology: normal (n=26), mild (n=30), moderate (n=123), severe (n=63) and extreme (n=43). Postoperative QuickDASH scores differed (p=0.046). The normal and extreme group showed higher QuickDASH scores than the severe group (p=0.02).

Figure 2: Proportion of patients with CTS and with a change in QuickDASH total score <8 (blue) in relation to electrophysiology grading. Normal (11/26, 42%), mild (13/30, 43%), moderate (35/123, 28%), severe (14/63, 22%) and extreme (8/43, 19%).

Figure 3. Linear regression showing no correlation (Spearman's r 0.003, n=308, p>0.05) between preoperative QuickDASH scores and sensory conduction velocity (SCV) in median nerve sensory branch at the wrist.



100
80
60
40
20
0
Postoperative QuickDASH score
Normal
Mild
Moderate
Severe
Extreme
Electrophysiology grading


100%
80%
60%
40%
20%
0%
Normal
Mild
Moderate
Severe
Extreme
Electrophysiology grading
Change >8
Change <8

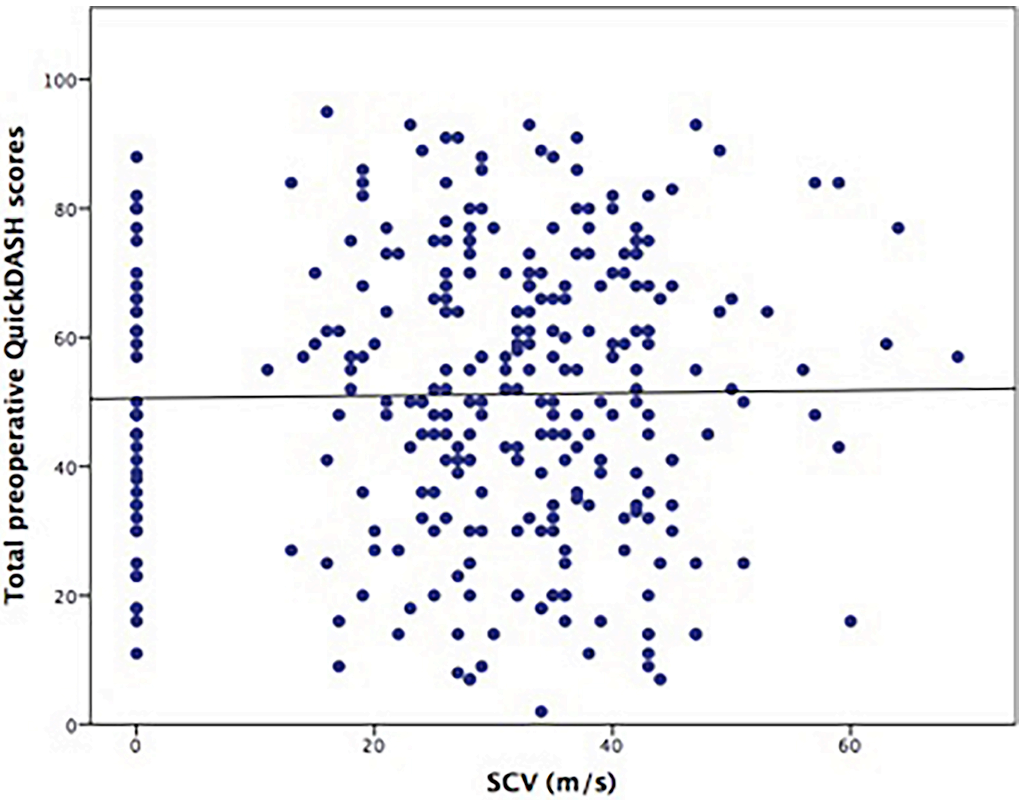

Total preoperative QuickDASH scores
100
80
60
40
20
0
0
20
40
60
SCV (m/s)

Table I. Clinical characteristics in 493 patients with carpal tunnel syndrome (CTS) treated with open carpal tunnel release.

	Smoking n=94	Non-smoking n=392	Change <8 n=124	Change >8 n=369	Total n=493
Gender (female)	72 (77)	268 (69)	84 (68)	259 (71)	343 (70)[a]
Age (years)	52 [45-60]	57 [48-69] *	56 [46-69]	55 [45-66]	55 [45-66] [a]
BMI	27 [24-32]	27 [25-31]	27 [24-30]	27 [25-31]	27 [24-31] [a]
Smoking			31 (25)	63 (17)	94 (19)
Diabetes Mellitus	15 (16)	61 (15)	24 (19)	52 (14)	76 (15) [a]
Hypertension	19 (20)	124 (32) *	38 (31)	105 (28)	143 (29) [a]
Exposure to vibrations	4 (4)	23 (7)	9 (8)	18 (5)	27 (6)
Polyneuropathy	7 (7)	18 (4)	12 (9)	14 (4) *****	26 (5) [a]
Electrophysiology-verified diagnosis	61 (65)	234 (60)	83 (67)	216 (59)	299 (61)
Conduction velocity median nerve sensory branch over the wrist (m/s)	35 [26-39]	29 [21-38] *****	34 [26-43]	29 [21-37] *****	31 [23-38] [a]

SNAP middle finger (mV)	6.0 [3.0-11.0]	3.0 [0.0-8.0] *****	5.0 [2.0-10.5]	3.0 [0.0-8.0] *****	4.0 [1.0-8.0]

Comparing the smoking patients vs. non-smokers as well as the patients that had a change in QuickDASH total score <8 vs. the patients that had a change in QuickDASH total score >8. All patients presented together in the last column for reference. In 7 cases data on smoking status was missing and could therefore not be included in the comparison. Nominal data presented as number (%). Continuous data presented as median [IQR]. *p<0.05

[a]Data already published (Zimmerman et al., 2016)

Zimmerman M, Dahlin E, Thomsen NO, Andersson GS, Bjorkman A, Dahlin LB. Outcome after carpal tunnel release: impact of factors related to metabolic syndrome. Journal of plastic surgery and hand surgery. 2016: 1-7.

Table II. QuickDASH scores in 493 patients with carpal tunnel syndrome (CTS) operated with open carpal tunnel release.

	Smoking n=94	**Non-smoking n=392**	**Change <8 n=124**	**Change >8 n=369**	**Total n=493**
Total preoperative QuickDASH score	61 [45-74]	48 [30-64] **	48 [26-64]	50 [34-68]	50 [32-66] [a]
Total postoperative QuickDASH score	34 [14-61]	16 [5-41] **	56 [30-73]	11 [3-31] **	18 [5-45] [a]
Change in total QuickDASH score	20 [5-36]	21 [9-36]	-2 [-11-4]	30 [18-41] **	21 [8-36] [a]
Change in total QuickDASH score <8	31 (33)	92 (23)			124 (25) [a]
Total postoperative QuickDASH score >10	73 (77)	232 (59) *	110 (90)	198 (53) **	308 (63) [a]
Change in total QuickDASH	21 (23)	146 (38) *			171 (35)

score >8 and total postoperative QuickDASH score <10

Comparing the smoking patients vs. non-smokers as well as the patients that had a change in QuickDASH total score <8 vs. the patients that had a change in QuickDASH total score >8. All patients presented together in the last column for reference. In 7 cases data on smoking status was missing and could therefore not be included in the comparison. Nominal data presented as number (%). Continuous data presented as median [IQR]. *p<0.05, **p<0.0001

[a]Data already published (Zimmerman et al., 2016)

Zimmerman M, Dahlin E, Thomsen NO, Andersson GS, Bjorkman A, Dahlin LB. Outcome after carpal tunnel release: impact of factors related to metabolic syndrome. Journal of plastic surgery and hand surgery. 2016: 1-7.

Table III. Logistic regression of hands with carpal tunnel syndrome (CTS) treated with open carpal tunnel release.

	Change in QuickDASH total score <8	**Postoperative QuickDASH score >10**
	OR	**OR**
Smoking	1.61 (0.98-2.62)	2.40 (1.42-4.06)**
Model 1	1.63 (0.99-2.75)	2.31 (1.33-4.03)*
Model 2 §	1.82 (0.93-3.57)*	2.47 (1.11-5.50)
SNAP middle finger §	1.05 (1.00-1.10)*	1.03 (0.99-1.08)
Model 1	1.06 (1.00-1.11)*	1.04 (0.99-1.10)
Model 2	1.01 (0.94-1.08)	1.02 (0.95-1.10)
SCV median nerve at wrist level §	1.02 (1.00-1.04)	1.01 (0.99-1.03)
Model 1	1.02 (1.00-1.05)	1.01 (0.99-1.04)
Model 2	1.02 (0.99-1.05)	1.00 (0.98-1.04)

Model 1 = adjusted for BMI, hypertension, diabetes, exposure to vibrations, polyneuropathy, age and sex

Model 2 = model 1 with SNAP middle finger, SCV median nerve at wrist level and smoking added

Dependent variables: change <8 in QuickDASH total score, postoperative QuickDASH score >10.

§283 patients included in the analysis

*p<0.05 **p<0.001